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^{137}Cs VERTICAL DISTRIBUTION IN SOILS OF THE POLISSYA REGION OF UKRAINE

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The article examines the peculiarities of radionuclide ^{137}Cs vertical migration in soil on different types of phytocenoses in Polissya, Ukraine. The study's pertinence stems from the necessity to monitor the processes of vertical migration of the predominant dose-forming isotope ^{137}Cs in the soils of Ukraine, nearly four decades following the incident at the Chernobyl Nuclear Power Plant. The objective of the present study was to ascertain the distribution of radionuclide ^{137}Cs in the soil profile of sod-podzolic and meadow soils. The study employed a method of layer-by-layer sampling of soil samples (at intervals of 5 cm to a depth of 50 cm) and utilised the gamma-spectrometric method of measuring the ^{137}Cs activity concentration. The primary outcomes of the study are the identification of substantial variations in the ^{137}Cs vertical distribution, contingent on the nature of land use and the geographical location of sampling points within phytocenoses. In forest ecosystems and virgin areas (e.g., unplowed pastures), the majority of activity (60–70 %) is concentrated in the upper 10 cm layer, with less than half (approximately 48 % in forest ecosystems and 30 % in pastures, respectively) occurring in the 0–5 cm layer. This finding is indicative of the radionuclide's gradual penetration into the soil. Concurrently, in regions exhibiting intensive economic utilisation or mechanical soil cultivation (plowing), there is an almost uniform distribution of ^{137}Cs in the 0–35 cm layer, with an average of 93 % of the total radionuclide activity in the profile concentrated in this layer. It was concluded that the slow migration of the isotope and its physical decay contribute to the improvement of the radiological condition of radionuclide-contaminated areas. However, the heterogeneity of the vertical distribution increases the uncertainty of the assessment of soil contamination density in the long term. The authors recommend the collection of soil samples at a depth of a minimum of 20–25 cm (and up to 30–35 cm on arable land) in order to ascertain the density of ^{137}Cs contamination. This differs from some existing recommendations for soil sampling when conducting a radioecological assessment of areas contaminated with radionuclides in the aftermath of the Chernobyl accident. It was also noted that the prospect of using the RKG-14 Virtuoso radiometer to determine the density of ^{137}Cs contamination of territories based on the results of direct measurements taken on site was also discussed. *Key words:* radioactive contamination density, vertical migration of ^{137}Cs in soil, radioactive contaminated areas.

Вертикальний розподіл ^{137}Cs в ґрунтах Полісся України. Іллєнко В.В., Сальнікова А.В., Гнедко А.М., Біленко В.О., Радченко В.Д., Лазарєв Д.М.
У статті досліджено особливості вертикальної міграції радіонукліду ^{137}Cs у ґрунті на різних типах фітоценозів Полісся України. Актуальність дослідження зумовлена необхідністю моніторингу процесів вертикальної міграції основного дозоутворюючого ізотопу ^{137}Cs в ґрунтах України через майже 40 років після аварії на Чорнобильській АЕС. Мета дослідження полягала у визначенні розподілу радіонукліду ^{137}Cs в ґрунтовому профілі дерново-підзолистого та лучного ґрунту. У дослідженні використовувалися методи пошарового відбору ґрунтових зразків (з інтервалом 5 см до глибини 50 см) та гамма-спектрометричний метод вимірювання питомої активності ^{137}Cs. Основними результатами роботи є встановлення суттєвих відмінностей у вертикальному розподілі ^{137}Cs залежно від типу використання земель і також залежно від точок відбору зразків у межах однакових фітоценозів. У лісових екосистемах та на цілинних ділянках (наприклад, пасовищах без оранки) основна частина активності (60–70 %) зосереджена у верхньому 10-сантиметровому шарі, причому менше половини (близько 48 % у лісових екосистемах та 30 % на пасовищах, відповідно) – у шарі 0–5 см. Це свідчить про повільне проникнення радіонукліду вглиб. Водночас, на ділянках з інтенсивним господарським використанням або механічним обробітком ґрунту (оранкою), спостерігається майже рівномірний розподіл ^{137}Cs у шарі 0–35 см, в середньому 93 % всієї активності радіонукліду в профілі зосереджено в цьому шарі. Зроблено висновок, що повільна міграція ізотопу та його фізичний розпад сприяють покращенню радіологічного стану забруднених радіонуклідами територій, але неоднорідність вертикального розподілу підвищує невизначеність оцінки щільності забруднення ґрунту у довгостроковій перспективі. Автори рекомендують відбирати проби ґрунту на глибину не менше 20–25 см (а на орних землях – до 30–35 см) для визначення щільності забруднення ^{137}Cs, що відрізняється від деяких існуючих рекомендацій щодо відбору зразків ґрунту при проведенні радіоекологічної оцінки територій, забруднених радіонуклідами після аварії на Чорнобильській АЕС. Відмічено також перспективність використання радіометру РКГ-14 «Virtuoso» для визначення щільності забруднення територій за результатами прямих вимірювань безпосередньо на місцевості. *Ключові слова:* щільність забруднення радіонуклідами, вертикальна міграція ^{137}Cs в ґрунті, радіоактивно забруднені території.

Analysis of research and publications. In the aftermath of the Chernobyl incident, there has been a substantial enhancement and stabilisation of the radiation situation in Ukraine. In comparison with 1986, the radiation background has decreased by hundreds of times, primarily due to the physical decay of radionuclides, their penetration into the soil, and their removal with plant products. The fixation of radionuclides by the soil complex (mainly cesium isotopes) and the intensive implementation of anti-radiation measures in the early 1990s in the agricultural sector led to a decrease in the content of radionuclides in agricultural products, which, as a result, led to a decrease in the radiation doses received by the population [1–3].

Another potential explanation for the observed decline in activity pertains to the redistribution of radionuclides within the soil profile, coinciding with the gradual deepening of the root-containing layer. Consequently, this phenomenon also exerted an influence on the availability of radionuclides to plants. It is widely acknowledged that soil is regarded as the primary repository for the accumulation of radioactive ^{137}Cs (one of the predominant dose-forming isotopes outside the exclusion zone) [4, 5]. From soil begins ^{137}Cs migration path through food chains through food products to the human body.

The vertical migration of ^{137}Cs is a continuous process, but its rate of movement varies significantly depending on the type of soil. For instance, the absence of clay minerals, elevated pH values, and increased humidity have been demonstrated to accelerate the penetration of radionuclides. According to experts in the field, the rate of this process is less than 1 cm/year and only slows down over time. This is associated with the processes of ^{137}Cs binding by the soil-mineral complex and the circulation of elements in the upper soil layer due to biota [6, 7]. Furthermore, given the substantial mosaic nature of the contamination and the presence of a large number of different soil types in the Chernobyl fallout zone, the study of activity redistribution in the soil profile requires constant attention from scientists.

Research undertaken in diverse regions of the Ukrainian Polissya forests has demonstrated that the maximum values of ^{137}Cs activity concentration in the mineral component of the soil were identified in the 0–4 cm stratum of the humus-eluvial horizon. In fresh pine forests, the activity levels of the indicator were recorded at 1450 ± 36 Bq/kg, and in fresh sub-pine forests, the levels were determined to be 1187 ± 31 Bq/kg, constituting 8 to 15 % of the total activity. It was observed that as the soil was penetrated, there was a gradual decrease in the ^{137}Cs activity concentration. The predominant content of ^{137}Cs is found within the 0–24 cm mineral layer of the soil [8].

As indicated by scientific publications, the ^{137}Cs mobility in soil is determined by a combination of factors, including the presence of organic matter, the granulometric composition (i.e. the relative proportion of clay minerals and oxides), the pH level, the potassium content, and the mineral sorbents. Liming, potash fertilisation, and high organic matter content have been shown to reduce the availability of cesium to plants (through competition and sorption). In contrast, fires, erosion, and bioturbation have been demonstrated to promote redistribution and deeper migration of ^{137}Cs [9].

Analyses of the effects of peatland and grassland fires demonstrate that the heating and burning of litter results in alterations to the vertical profile. Accumulated radionuclides, such as ^{137}Cs, within the organic layer can be transferred to the upper mineral horizons or removed in aerosol form, thereby modifying the local activity ratios within the layers. Furthermore, mechanical disturbances (e.g. logging, craters, technogenic impacts) contribute to the mixing of horizons and deeper penetration of radionuclides [10, 11].

As indicated by recent estimations undertaken several decades subsequent to the Chernobyl incident, the distribution of ^{137}Cs in Polissya remains relatively stable within the upper layers. Nevertheless, local deviations have been observed as a consequence of natural processes (e.g. bioturbation, erosion, peatland transformations) and anthropogenic influences (e.g. forest fires, economic activity) [12]. In practice, this necessitates the incorporation of quantitative parameters of the vertical redistribution of ^{137}Cs (in addition to integral values on the plane) in the assessment of radiological safety, given that visible maxima in the substrate/upper centimetres determine the risk of radioactive contamination of mushrooms, berries, forest herbs and fodder crops. Furthermore, deeper migration affects the contamination of plants with deep root systems, such as root crops, with radionuclides [8].

Materials and Methods. The research was conducted in 2025 in areas proximate to the settlements of Narodychi and Bobrychi, in the Zhytomyr region, within forest, agricultural, and meadow ecosystems. Nine soil test pits, with a depth of 50 centimetres, were excavated, and soil samples were collected in 5-centimetre layers to ascertain the activity concentration of ^{137}Cs. The coordinates of the test pits and the average values of the ambient equivalent dose rate (AEDR) of gamma radiation, measured using the RKG-14 Virtuoso radiometer (Ecotest), are given in Table 1. The density of ^{137}Cs contamination in the soil was measured at the sampling points using a RKG-14 radiometer; the device was placed at a height of 10 cm from the soil surface.

A total of 90 soil samples were collected and analysed. Soil samples were prepared for gamma spectrometry to measure the content of ^{137}Cs, utilising established methodologies [13]. The ^{137}Cs activity concentration was measured using a SEG-001 'AKP-S'-63 spectrometer (AtomKompleksPrylad) with a NaI(Tl) scintillation detector in 130 cm^3 Denta vessels [14]. The soil type at the sampling sites was sod-podzolic (forest ecosystems and agricultural land) and meadow (pastures in the floodplains of the Uzh and Zherev rivers). The subsequent calculations and statistical processing of the results were performed in MS Excel 2016.

The objective of the present study was to examine the present vertical distribution of ^{137}Cs in the soils of the Ukrainian Polissya in forest ecosystems, agricultural land and pastures.

Table 1

Sampling sites

Sampling point	Geographical coordinates		AEDR, μSv/h
	Latitude	Longitude	
Forest			
Soil test pit 1	51°13’3.157”N	29°5’43.459”E	0,11 ± 0,01
Soil test pit 2	51°13’7.250”N	29°5’38.133”E	0,12 ± 0,01
Soil test pit 3	51°13’21.388”N	29°2’56.117”E	0,10 ± 0,01
Pasture			
Soil test pit 4	51°8’50.261”N	28°15’7.233”E	0,08 ± 0,01
Soil test pit 5	51°12’7.834”N	29°6’13.362”E	0,15 ± 0,01
Soil test pit 6	51°12’8.392”N	29°6’31.498”E	2,00 ± 0,39
Agricultural land			
Soil test pit 7	51°9’7.390”N	28°13’51.974”E	0,14 ± 0,01
Soil test pit 8	51°8’33.207”N	29°5’4.673”E	0,21 ± 0,01
Soil test pit 9	51°8’59.370”N	29°5’58.727”E	0,20 ± 0,01

Results and Discussion. The ^{137}Cs activity concentration was measured for each individual soil layer, enabling a layer-by-layer calculation of the radionuclide density contamination at each sampling point, with the volume mass of the sample being taken into account. This facilitated the calculation of the total contamination density for the area, and subsequent isolation of the distribution of ^{137}Cs activity for each layer as a percentage of the total activity in the 0–50 cm profile.

As illustrated in Figure 1, the distribution of ^{137}Cs activity across the vertical profile of test pits 1–3, which were excavated in forest ecosystems, is depicted.

In particular, the values are expressed as a percentage of the total activity of the radionuclide in a 50-centimetre layer of soil, with the exclusion of forest litter. The highest activity concentration of the radionuclide is observed in the upper layers of the soil, with the 0–5 cm layer in particular exhibiting the highest percentage of ^{137}Cs activity. The mean value for the three analysed soil test pits is 47.9 ± 3 % of radionuclide activity, which persists in being concentrated in the upper 5-centimetre layer. This finding is consistent with the results of studies conducted by other scientists on forest ecosystems [10].

Furthermore, as depth is increased, a sharp decrease in the activity concentration of ^{137}Cs is observed. In the 5–10 cm layer, the percentage of radionuclide activity is almost twice as low (25.8 ± 6 %) than in the upper layer and continues to fall in the following layers (10–15 cm, 15–20 cm, and so on). Deep soil layers (25–30 cm and deeper) contain minimal ^{137}Cs activity, totalling approximately 7 % of the total activity observed in the profile. The results of three test pits show that, on average, 90.6 % ± 4 % of ^{137}Cs activity is concentrated in the 0–20 cm layer of forest soil.

These data indicate that after contamination due to radioactive fallout in 1986, most of the ^{137}Cs (more than 70 %) remains in the upper 10 cm layer of soil.

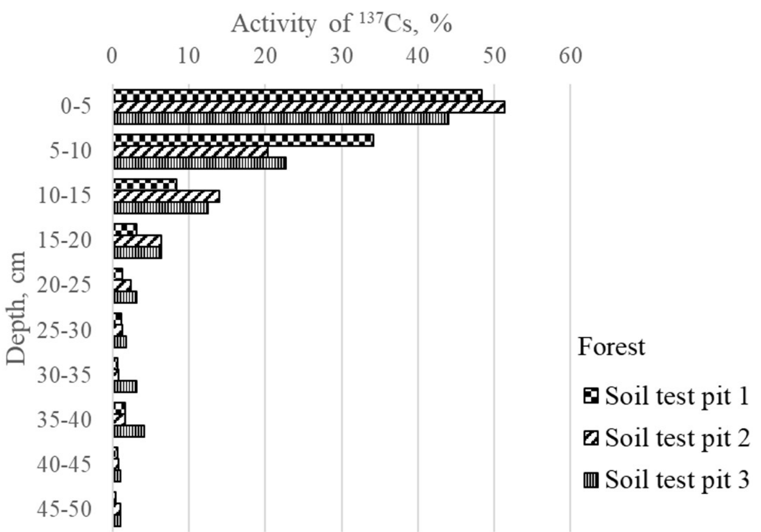

Fig. 1. Vertical distribution of ^{137}Cs within the forest soil profile (based on three soil test pits)

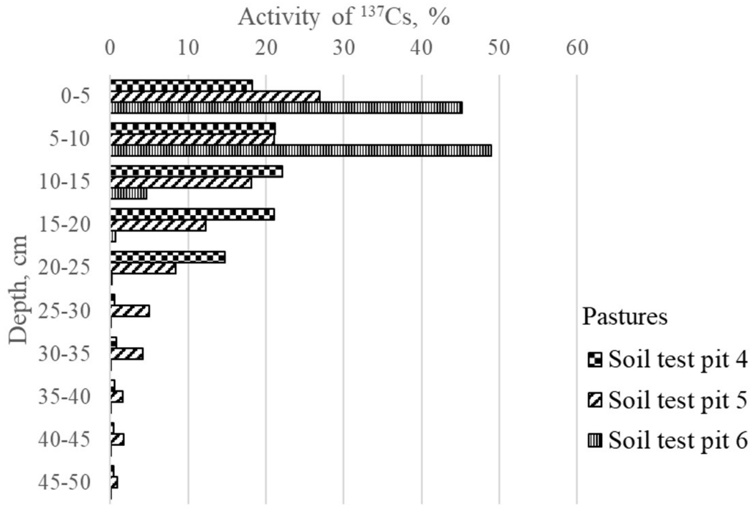

Fig. 2. Vertical distribution of ^{137}Cs within the pasture soil profile (based on three soil test pits)

Its penetration into deeper layers is quite slow, which is typical for this radionuclide in forest ecosystems [15]. In addition, other authors note a significant reserve of radioactive ^{137}Cs in forest litter [8, 9].

Fig. 2 shows the distribution of ^{137}Cs in the vertical profile of meadow soil on pastures (soil test pits 4–6).

As illustrated in the diagram, the majority of the ^{137}Cs activity is concentrated in the upper layers of soil, at a depth of up to 20 centimetres. This layer is of critical importance for pastures, as it contains the bulk of the plant root system and accounts for between 62 % and 98 % (with an average of 86.8 ± 9 %) of the total activity of the radioactive isotope in the soil profiles studied. It is noteworthy that a 'spot' (Fig. 3) with a significantly higher level of radioactive contamination than the main area of the pasture (soil test pit 6) has been identified in the 0.2 ha area of the floodplain of the Uzh River.

Furthermore, there is a divergence in the patterns of vertical distribution of radioactivity. In contrast to test pit 4 and 5, where almost uniform radioactive contamination is observed in the 0–20 cm layer, at this point the main activity of ^{137}Cs is concentrated in the 0–10 cm layer. In terms of landscape, the most contaminated area is located in a small depression, which causes water stagnation after the spring-autumn flooding of the Uzh River. This leads to the gradual horizontal washing away of radionuclides along with the top layer of soil, and the concentration of its activity at the lowest points of the depression. Here, the indicated local levels of radioactive contamination have formed, and practically all of the ^{137}Cs radioactivity was found in the top ten centimetres of soil.

The layer-by-layer distribution of radionuclide activity in the soil profile at pits 4 and 5 is well consistent with each other. When the results of these two points are

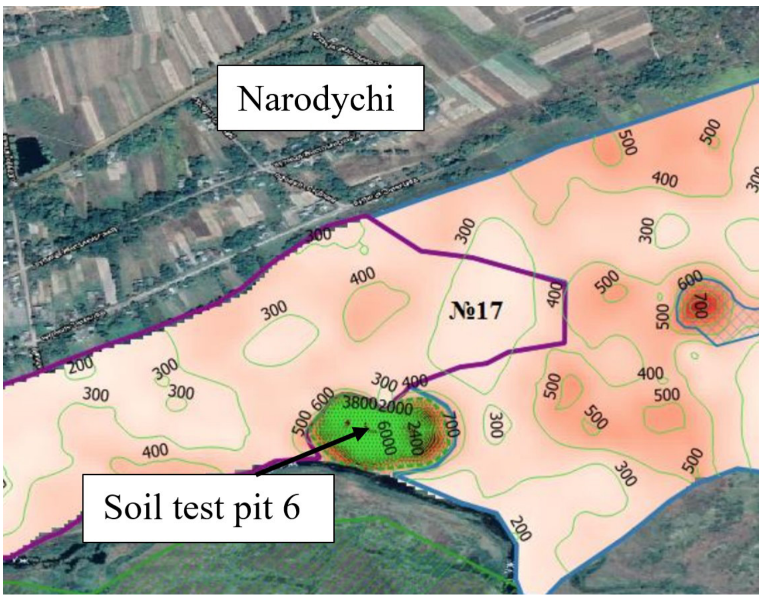

Fig. 3. An uneven distribution of ^{137}Cs contamination density is evident in the pasture area located to the north of the settlement of Narodychi. (*part of Fig. 1a from* [16])

analysed separately, a practically uniform distribution of ^{137}Cs activity is observed in the 0–5 cm, 5–10 cm and 10–15 cm layers – on average 22.6 ± 3 %, 21.1 ± 2 % and 20.1 ± 2 % respectively. This is followed by a gradual decrease in radionuclide activity with increasing sampling depth. In layers deeper than 25 centimetres, the activity of ^{137}Cs becomes minimal, accounting for approximately 5.4 % of the total activity in the profile.

The results obtained demonstrate that in pastures, the majority of the radioactive contamination of ^{137}Cs is concentrated in the 0–20 cm layer and continues to slowly descend into the lower layers of the profile. It is also noteworthy that the upper 5 cm layer of soil in pit 4 contains 18.3 ± 2 % of radionuclide activity, while the subsequent three layers (5–10 cm, 10–15 cm and 15–20 cm) contain more than 21 % each. This finding suggests that, approximately 40 years following the initial contamination, the presence of ^{137}Cs in the soil profile has gradually diminished, thereby reducing its activity at the surface. In conjunction with the processes of physical decay of radionuclides, this contributes to a significant improvement in the radiological condition of natural pastures and creates opportunities for their use as a feed base for farm animals [16].

The patterns of vertical distribution of ^{137}Cs radioactivity in natural floodplain pastures indicate the necessity of accounting for contemporary changes in the vertical distribution of ^{137}Cs when selecting soil samples for the purpose of evaluating the density of radioactive contamination of natural ecosystems. This is particularly relevant when the sample is taken at a depth of up to 10 cm, as recommended. These recommendations were pertinent in the initial decades following the radioactive contamination; however, it is imperative to acknowledge that a substantial proportion of the radioactive caesium is situated beneath a depth of 10 cm. This is of particular importance when determining the initial level of radioactive contamination based on retrospective calculations.

As illustrated in Figure 4, the distribution parameters of ^{137}Cs in the vertical profile of sod-podzolic soil on agricultural land (probes 7–9) are demonstrated.

As with pastures, an uneven vertical distribution of ^{137}Cs is observed in the soil profile at three sampling test pits. In particular, for pit 7, a concentration of ^{137}Cs was noted in the upper layer (0–15 cm), with a subsequent sharp decrease in activity in deeper layers. This distribution is more characteristic of soils in natural ecosystems, where no ploughing or other mechanical tillage was carried out after radioactive contamination. However, at the time of sampling at sampling test pit 7, the field had been sown with oats. It is hypothesised that the increasing prevalence of soil cultivation technologies that do not involve ploughing may be a contributing factor to this phenomenon. In the aftermath of the Chernobyl incident, the agricultural fields located to the north of the village of Narodychi were designated as zones 2 and 3 of radioactive contamination, resulting in a prolonged period of non-cultivation. It is evident that, in recent times, a marked enhancement in the radioecological situation has been observed, resulting in a gradual reintroduction of these territories to economic utilisation. Furthermore, this frequently occurs as a consequence of the unauthorised utilisation of radioactive contaminated areas [17]. It is equally important to consider the influence of soil cover heterogeneity, which has the capacity to affect the intensity of vertical radionuclide migration [18].

For test pits 8 and 9, the distribution of the radionuclide ^{137}Cs in the soil profile is found to be highly analogous. The distribution of radionuclide activity is practically uniform in the layer ranging from 0 to 35 cm (up to 15 % of the total activity in each 5 cm layer), with an average value for the three sampling points of 93.0 ± 2 %. In strata beneath 35 centimetres, the activity is negligible, and in the 45–50 centimetre range, it is almost undetectable.

When analysing the results obtained, it is also worth paying attention to the issue of increasing uncertainties

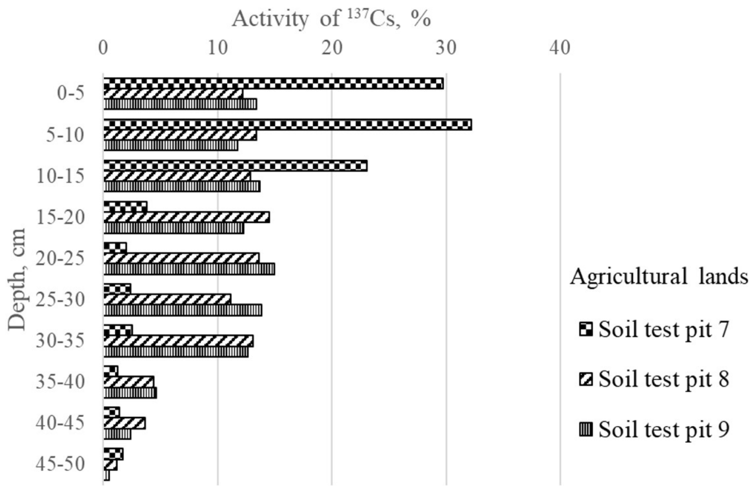

Fig. 4. Vertical distribution of ^{137}Cs within the agricultural land soil profile (based on three soil test pits)

in assessing such an important indicator as the density of soil contamination with radionuclides. The density of soil contamination by radionuclides is an indicator of the amount of radioactive substances per unit area of soil, which is typically measured in curies (Ci) per km^2 or becquerels (Bq) per m^2. This indicator is pivotal in evaluating the radioecological status of territories and formulating measures for their rehabilitation [19, 20]. Therefore, in order to most accurately determine the density of radionuclide contamination in an area, it is important to understand the depth to which radioactive isotopes have penetrated at the study site, and to take samples at that depth.

In the course of nearly four decades of observation of the migration of radionuclides from the Chernobyl fallout in the environment, there have been changes in the recommendations regarding the depth of soil sampling for the purpose of assessing the density of radioactive contamination of the territory. In the initial years following the incident, the majority of radionuclide activity was observed to be concentrated within the upper soil layer (0–5 cm), and it was deemed unwise to collect samples deeper than 10 cm.

Long-term observations of the ^{137}Cs and transuranic elements vertical migration demonstrate that, as of the early 2000s, the majority of these elements within the contaminated area of the Chernobyl incident are found in the uppermost 0–10 cm layer of soil. Consequently, when evaluating the density of soil contamination with these radionuclides, it is currently adequate to take samples to a depth of 10 cm in virgin areas [21]. In the aforementioned publication [22], the authors recommend the collection of soil samples to a depth of at least 20 centimetres in order to ascertain the content of ^{137}Cs in both virgin and ploughed soils. The IAEA's recommendations on the vertical distribution of radionuclides from the Chernobyl accident indicate that more than 80 % of ^{90}Sr, ^{137}Cs, ^{154,155}Eu, $^{238–240}$Pu and ^{241}Am remained in the surface (0-10 cm) soil layer 30 years after the fallout. With regard to the recommended sampling depth, it is advised that samples be taken at a depth of 20–30 cm on arable land [20].

The findings of this research have been collated in Table 2, which details the results of determining soil contamination density when sampling at different depths. Furthermore, the results of the measurement of the density of radionuclide contamination of the territory with ^{137}Cs using an RKG-14 radiometer are also contained herein.

A comparison of the results of our research and the recommendations in the aforementioned publications reveals that when sampling forest ecosystems at a depth of 0–10 cm, we collect 74 ± 7 % of ^{137}Cs, while sampling at a depth of 0–20 cm collect 91 ± 4 % of ^{137}Cs, respectively. For pastures, we have the following picture: sampling depth 0–10 cm – 61 ± 24 % of ^{137}Cs, sampling depth 0–20 cm – 87 ± 9 % of ^{137}Cs, have been collected in a sample, respectively. In the context of sampling on agricultural land, it would be prudent to extend the sampling depth to 30 cm. This approach would ensure the incorporation of 84 ± 7 % of ^{137}Cs into the analysis. Conversely, the sampling of the 0–20 cm layer resulted in the absorption of 64 ± 17 % of the radionuclide in a sample.

In addition, it is considered that the utilisation of the RKG-14 radiometer holds considerable potential in the facilitation of the determination of the territories contamination density. The correlation coefficients between the results of layer-by-layer determination of the ^{137}Cs territory contamination density at 0–10 cm, 0–20 cm and 0–50 cm and the results of radiometer measurements are 0.998, 0.997 and 0.996, respectively, which confirms a strong correlation between the measurement results. It is evident that physical sampling and the subsequent measurement of activity using stationary spectrometers in a laboratory setting

Table 2

^{137}Cs soil contamination density, kBq/m^2

Sampling point	For a layer of 0–50 cm	For a layer of 0–10 cm	For a layer of 0–20 cm	Result of measurement with the RKG-14 radiometer
Forest				
Soil test pit 1	146.9 ± 27.0	121.3 ± 12.7	138.2 ± 17.0	53.3 ± 11.3
Soil test pit 2	49.2 ± 28.2	35.3 ± 5.3	45.3 ± 9.0	71.6 ± 15.2
Soil test pit 3	79.0 ± 15.2	52.7 ± 5.3	67.6 ± 8.0	63.9 ± 13.6
Pasture				
Soil test pit 4	55.3 ± 26.0	21.8 ± 2.5	45.7 ± 5.4	11.4 ± 2.4
Soil test pit 5	181.4 ± 25.6	87.0 ± 8.7	142.0 ± 14.6	25.7 ± 5.4
Soil test pit 6	3489.2 ± 621.1	3285.0 ± 328.5	3470.5 ± 347.1	1106.4 ± 222.3
Agricultural land				
Soil test pit 7	39.6 ± 22.1	24.5 ± 3.1	35.2 ± 5.5	8.9 ± 1.9
Soil test pit 8	147.0 ± 18.7	37.6 ± 4.3	77.9 ± 9.0	16.9 ± 3.6
Soil test pit 9	100.7 ± 29.4	25.3 ± 3.9	51.4 ± 7.5	11.3 ± 2.4

are indispensable components of the research process. However, it is conceivable to augment the number of points collected during the survey of a given territory. Furthermore, when a sufficient sample of measurement results is available, it is possible to determine the necessary correction factors when working with a RKG-14 radiometer for different types of land. This will minimise the number of samples taken, reduce the cost of the survey and maintain the necessary accuracy of the assessment of the ^{137}Cs density contamination of the soil.

Conclusions. The data obtained indicate that following the 1986 radioactive fallout, the majority of the ^{137}Cs (over 70 %) in forest ecosystems remains concentrated in the upper 10-centimetre layer of soil. The penetration of this radionuclide into deeper layers is very slow, which is a characteristic feature of these ecosystems.

The findings of research conducted on pastures indicate that the activity of ^{137}Cs is localised in the 0–20 cm layer and only gradually moves down the soil profile. In particular, in soil test pit 4, the upper 5 cm layer contains approximately 18 % of the activity, while the subsequent layers (5–10 cm, 10–15 cm and 15–20 cm) accumulate more than 21 % each. This finding suggests that, approximately four decades following the incident, the radionuclide concentration in the surface horizon has diminished significantly as a result of slow migration in a downward direction and natural radioactive decay. Furthermore, the distribution of the radionuclide throughout the soil profile at the study sites was found to be uneven.

A similar trend is also observable in other points studied on agricultural land, which demonstrate an uneven vertical distribution of ^{137}Cs. In the seventh soil test pit, the radionuclide is predominantly concentrated within the upper 0–15 centimetres, after which its activity undergoes a precipitous decline. Test pits 8 and 9 are characterised by an almost uniform distribution of ^{137}Cs in the 0–35 cm layer, where each 5 cm horizon contains up to 15 % of the total activity. As the measurement falls below 35 centimetres, the activity undergoes a rapid decrease. In the 45–50 centimetre layer, the ^{137}Cs activity becomes practically undetectable.

The authors of the study recommend the collection of soil samples to a depth of at least 20–25 cm (and for arable land up to 30–35 cm) in order to accurately determine the ^{137}Cs density contamination in the areas. In this case, approximately 90 % of the radionuclide activity will be collected with the samples and taken into account when determining the territory contamination density. Furthermore, the potential of employing the RKG-14 radiometer for direct estimation of contamination density in the field is underscored.

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